Effects of Carbon Emission on Melting of ICE

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Abstract— We burn fossil fuels such as gas, coal or oil, through which carbon dioxide is released into the atmosphere. In a natural carbon cycle, carbon dioxide is re-absorbed by plants and trees. However, we are burning fuels where the carbon dioxide has been trapped under the earth's surface for millions of years, and we're doing it so quickly that plants and trees that are alive now have no chance of soaking it up resulting adverse impacts on the atmosphere. The effect of all this extra carbon dioxide in the atmosphere is that the overall temperature of the planet is increasing (global warming). Whilst the average global temperature is increasing, on a day-to-day level the climate is changing in unpredictable ways (from floods and hurricanes to heat waves and droughts). To try and reduce the risk of ever more extreme weather, we need to reduce how much fossil fuel we are burning. In this paper I have discussed about global scenario of carbon emissions, different trends in top six largest emitting countries, other developing countries, comparison of carbon emissions in different countries, effects of carbon emission on snow melting, etc. and how the effects of carbon emission can be reduced.

Key words: Carbon Emission, ICE, Snow Melting

I. INTRODUCTION

CO2 emissions originate for 90% from fossil-fuel combustion and therefore are determined by the following three main factors:

- Energy demand or the level of energy-intensive activity; in particular, related to power generation, basic materials industry and road transport;
- Changes in energy efficiency;
- Shifts in fuel mix, such as from carbon-intensive coal to low-carbon gas, or from fossil fuels to nuclear or renewable energy.

Important drivers of specific fossil-fuel consumption are the fuel price, in general, and relative price differences between coal, oil products and natural gas. Of course, energy policies also are aimed to manage fossil-fuel use. In addition, energy consumption is affected by certain preconditions, such as weather: warm or cold winters affect the demand for space heating and in some countries hot summers affect the demand for air conditioning. Moreover, the topography, orography and climate of a country affect activities such as distances travelled and the potential for renewable energy such as hydropower, wind, solar and tidal energy.

For CO2 emissions it is important to note that natural gas (~15 kg C/GJ) per unit of energy contains roughly half the amount of carbon (C) compared to coal (~26 kg C/GJ), with the amount of carbon in oil products somewhere in between (~20 kg C/GJ). Thus, the combustion of coal produces about 75% more CO2 than that of natural gas. Industry, in particular iron and steel manufacturing, is the second largest source. The use of coal is country-specific: the share of coal in the energy mix of the top-25 countries varies from 33% in the United States to 43% in India, 47% in China and 49% in Poland. Swart and Weaver (2012) also point to the large tonnage of coal available and its high carbon content in comparison to other fossil-fuel resources. The known reserves of global coal resources would cause 5 times more CO2 emissions, if all would be consumed, compared to the CO2 emitted from the consumption of all global shale gas and oil resources. Shale gas and oil, in turn, would cause 10 times more CO2 emissions, if all would be consumed, compared to the total in Conventional global gas and oil resources.

II. GLOBAL SCENARIO OF CARBON EMISSIONS

The Global CO2 emissions, 2012 was a remarkable year in which emissions increased by only 1.1%, which is less than half of the average annual increase of 2.9% seen over the last decade, reaching a new record of 34.5 billion tonnes. After a 1% decline in 2009, A 4.5% recovery in 2010, and a 3% increase in 2011, the actual 2012 increase in global CO2 emissions of 1.4% (i.e. excluding leap-year effect) is less than would be expected, given that in 2012, the global economy grew by 3.5%, which is similar to 2011 and to the average annual growth rate over the last decade (IMF, 2013). With a leap- year correction of 0.3% (=-1/365), the 2012 increase in global CO2 emissions was only 1.1%.

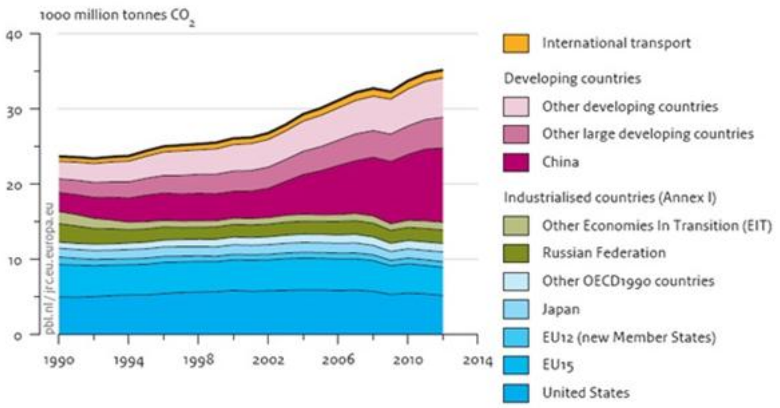

Fig 2.1: Global CO2 emissions per region from fossil fuel use and cement production

Global coal consumption (responsible for about 40% in total CO_2 emissions), in 2012, grew by only 0.9% ('actual') in 2012, well below the decadal average of 4% shown in Fig.2.1. These figures were calculated using the actual coal consumption increase in China of 2.5% in 2012, as reported by the National Bureau of Statistics of China (NBS, 2013), rather than the 2012 figure provided by BP (2013) that implies a 6.4% increase in 2012 compared to 2011. The BP (2013) release contains updates for the coal consumption data for China over the last four years, with annual increases now very similar to the data reported by China's NBS. In BP's release of last year the increase in China's coal consumption for 2010 was still estimated to be 10.1%, while the NBS reported this to be 5.9%. However, in their current report, BP has now revised their estimation for 2011 to 6.4%. Global consumption of natural gas and oil products increased by 2.2% and 0.9%, respectively, somewhat below the historical trends of 2.7% and 1.2%, annually.

The six largest emitting countries/regions (with their share in 2012 between brackets) were: China (29%), the United States (15%), the European Union (11%), India (6%), the Russian Federation (5%) and Japan (4%). Remarkable trends were seen in the top three emitting regions, which account for 55% of total global CO_2 emissions. In China emissions increased by 3.0%, while in the United States emissions decreased by 4.0% and the European Union as a whole also saw a decrease of 1.6% in 2012 compared to 2011. In the aftermath of the Fukushima nuclear accident, Japan's CO_2 emissions showed a 6.2% increase in 2012. Within the European Union, decreases were seen in, for example, Italy, Poland, Spain and the Nether lands, whereas emissions increased in the United Kingdom and Germany. The increase in China was equivalent to two-thirds of the net global CO_2 increase in 2012; for India this was one quarter and for Japan almost one fifth, whereas the United States accounted for minus 40% and the European Union for minus 10%, with changes in 2012 compared to 2011 expressed as a fraction of the net emission increase in 2012.

China's CO_2 emission increase of 3% in 2012 was about 4 percentage points less than its historical average increase in emissions. This was primarily due to a decline in electricity and fuel demand by the basic materials industry, as economic growth slowed down when the stimulus package was terminated and the production of hydropower rebounded, aided by an increase in the use of renewable energy and by energy efficiency improvements.

In the United States, a shift from coal to natural gas in power generation that caused a 12% reduction in coal consumption, together with increased renewable energy production, in particular wind and bioenergy, were the main drivers of the 4% drop in CO_2 emissions. The rapid expansion of gas-fired power generation in 2012 was caused by the rapid increase in shale gas production. This, in turn, led to the lowest natural gas prices in the United States in a decade, and caused a 3% decrease in the share of coal in the national fossil-fuel mix.

The European Union's CO_2 emission reduction of 1.6% (1.3% 'actual') in 2012, was 1% less than the historical trend, and this was partly due to the continued weak economic condition post-2009, with a 0.3% decrease in total GDP in 2012 (in PPP units; IMF, 2013). The companies covered by the EU Emissions Trading System (EU ETS) - more than 12,000 installations covering more than 40% of the EU's CO_2 emissions - reported 2% less in CO_2 emissions for 2012 than for 2011. The EU saw a 1.6% decrease in natural gas consumption, despite a higher demand for space heating in parts of Europe due to the cold winter. Europe's power industry took advantage of the drop in the US coal demand. The fact that the price of carbon credits in the EU ETS was too low to offset the price advantage of switching electricity production to more carbon-intensive coal, and that Europe started to import more coal, also from the United States, resulted in a 3.3% increase in EU-wide coal consumption.

The moderate 1.1% increase in global CO_2 emissions in 2012 seems remarkable in times where global economic growth was almost on a par with the average growth levels over the last decade. Within this percentage however, there are notable differences in the performance of various groups of countries. Economic growth in the industrialized OECD countries in 2012 was about two-thirds of the average over the past, while in eastern European countries ('Economies In Transition' or EIT) this was only half the level of the trend in recent history. In contrast, developing countries maintained their average growth of the previous decade. However, since a substantial part of a country's economy is made up of its service and agricultural sectors, which are not energy-intensive activities, increases in energy consumption are not always closely related to overall economic growth.

It is obvious that energy-intensive activities are of the highest relevance and that fossil-fuel combustion accounts for 90% of the total CO_2 emissions (excluding deforestation and other land uses). Power generation remains the most import sector related to fossil-fuel consumption; therefore, the choice of fossil fuel by the power sector is of the utmost importance .Contrary to the power industry, for which a relatively large variety of fuels can be selected (from fossil fuel to nuclear energy to renewable energy), other energy-intensive sectors, such as those of manufacturing and construction, are less flexible in the short term.

CO_2 emissions from cement clinker production (the largest source of non-combustion-related CO_2 emissions, contributing 4.5% to the global total) increased globally by 5% in 2012, mainly due to a 5% increase in the production in China, which accounts for more than half of total global production. The 2012 trend for CO_2 emissions from gas flaring (with a much smaller share in global emissions), generally contributing less than 1% to the global total, is not yet known, due to the absence of data updates from the NOAA satellite observation systems following changes in sensors.

The uncertainty in these figures varies between countries, ranging from 5% to 10% (95% confidence interval), with the largest uncertainties concerning data for countries with fast changing or emerging economies, such as the Russian Federation in the early 1990s and China since the late 1990s, and for the most recent statistics, based on Marland et al. (1999), Tu (2011), Andres et al. (2012) and Guan et al. (2012). Moreover, newly published statistics are often subject to subsequent revisions. Therefore, for China and the Russian Federation, we assumed 10% uncertainty, whereas for the European Union, the United States, Japan and India2, a 5% uncertainty was assumed. Our preliminary estimate for total global CO2 emissions in 2012 is believed to have an uncertainty of about 5% and the increase of 2.9% may be accurate to within 0.5%.

A. Different Trends in the Six Largest Emitting Countries/Regions

A comparison between the shares of national GDP (on the basis of Purchasing Power-Parity (PPP)) in global GDP showed that China's share in the world economy in 2012 was 15%, while the United States and the European Union each had a share of 19%, followed by India (6%), the Russian Federation (3%) and Brazil (3%). However, when looking at their contributions to the global economic growth over the last decade, which was 44% since 2002, China contributed 31%, India 10%, United States 9%, EU 8%, Russian Federation 4% and Brazil 3% (World Bank, 2013; IMF, 2013). In 2012, the growth in the world economy was around 3.8%, about the same level as that in the last ten years, apart from the global credit crunch years 2008- 2009, but with large differences between the largest countries/regions: China's annual economic growth in 2012 was only about three quarters of the decadal trend, so far the lowest this century. Economic growth rates of India (4.0%) and the Russian Federation (3.4%) were only half those of the recent past and that of Brazil (0.9%) only one quarter. The economy of the United States and Japan grew in 2012 by 2.2% and 2.0%, respectively, which closely represents their average historical growth rates, whereas the EU economy decreased by 0.3% which is shown in Fig.2.2.

For most industrialized countries, the past decade has been characterized mainly by the 2008-2009 recession, which has since been slowly recovering. In 2012, most OECD countries outside Europe saw their historical economic growth rates continued. The United States, Canada and Japan showed a GDP growth of about 2%, whereas in many EU countries, economic growth was very small or even negative.

1) China

In 2012, China's CO2 emissions increased by 3.3% ('actual') to 9.9 billion tonnes, the slowest rate of increase in a decade. This mainly was caused by a relatively small increase of 2.5% in domestic coal consumption, as reported by NBS (2013), whereas in the receding decade, the annual growth rate was mostly around 10%. Coal consumption was responsible for three quarters of China's CO2 emissions from fossil-fuel combustion. In contrast, natural gas consumption reached 10% in 2012, following annual increases of about 20%. If we had used BP's coal growth rate of 6.4% for China, the increase in CO2 emissions would come to 6.1% (BP, 2013). The increase of about 3% was the lowest since 2001, the year after which the increase in Chinese emissions on average accelerated from about 3% to 10%, annually. Even in the recent 'global recession' years, China's CO2 emissions continued to increase by about 6% per year.

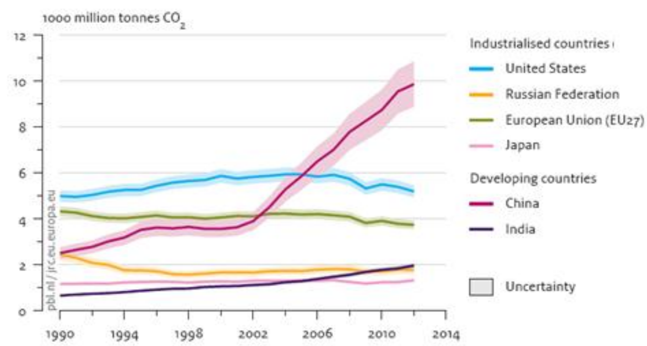

Fig. 2.2: CO2 Emissions from fossil-fuel use and cement production in the top 6 emitting countries and the EU

This relatively small increase in 2012 was consistent with the very small increase of 0.6% in thermal power generation (predominantly coal-fired power plants), 4.7% in steel production (also a large user of coal) and 5.3% in cement production, reported by the National Bureau of Statistics of China. The small increase in the kWhs generated by coal-fired power plants mainly was due to the large decline in the growth rate of electricity consumption to 4.8% in 2012, mainly from reduced industrial demand. In addition, power generation using hydropower increased by 23%, due to the expansion of installed capacity and recovery from the drop in 2011 due to drought. This large increase in hydropower production had a mitigating effect of around 1.5 percentage points on China's CO2 emissions in 2012. After years of double digit increases in GDP, China's increase in 2012 was only 7.8%. Unlike in developed countries, China's manufacturing industry is the sector with the largest consumption of electricity and fuels. Therefore, the demand for energy in general is largely driven by trends in basic materials production. At the end of 2008, China implemented a large economic stimulus package that effectively helped avoid the recession suffered by many other countries during 2008 and 2009. This package was aimed at countering a decline in economic growth; it included investment in transport infrastructure and housing development, and was terminated in 2011. Together with restrictions on investments in construction activities (buildings, power plants, infrastructure) this termination resulted in a substantial slowdown in the growth rate of the demand for materials, halving the growth in this sector. Thus, not only the growth of the Chinese economy but also of other key energy trend indicators, such as production of cement, steel and electricity, decreased significantly in 2012, compared to the high annual growth rates over the 2002-2011 period. The growth rate in cement, steel and electricity production was around 5.3% in 2012, which was almost half of that observed in previous years (except for 2007- 20083). Nevertheless, China's 2012 GDP growth of 7.8% was only about 3% less than the decadal average of around 10%.

With energy and, in particular, electricity demand in China growing half as fast as GDP in 2012, the energy intensity per unit of GDP declined by 3.6%, twice as fast as in 2011. This was caused by a slower economic growth and a structural change in growth. In this way, the country is expected to be able to achieve its 2015 target of a 16% cumulative reduction by the end of the 12th Five Year Plan, compared to 2010. The much smaller growth of 3.3% in total CO2 emissions (3.1% of which related to energy) and the relatively large GDP growth of 7.8% meant a reduction in carbon intensity of 4.3% in 2012.

To meet the intensity reduction target of close to 17% by 2015, relative to 2010, according to the 12th Five Year Plan (Fung, 2012), China's carbon intensity will need to continue to decrease but at a slightly higher rate (4.6%) for the three years following 2012. One strategy to reduce energy consumption would be to reorient the economy to the service sectors instead of manufacturing. In addition, more energy-intensive industries have begun to shift from the eastern provinces to less-developed central and western regions, to improve their energy efficiency and promote low carbon development, and this trend appears to be continuing (Fung, 2012). Moreover, the Chinese Government approved an energy consumption control target with the aim of bringing total energy consumption below 4 billion tonnes in standard coal equivalents by 2015.

2) United States

In the United States, in 2012, CO2 emissions decreased by 4% to 5.2 billion tonnes, following a 2% decrease in 2011. This emissions level was the lowest since 1993 and occurred while the economy was growing, whereas, since 2005, CO2 emissions had been increasing every year, with the exception of 2010. The large decrease in 2012 was mainly due to a decrease in the use of coal (mostly used in power generation). The large increase in shale gas production caused natural gas prices to decline in the first half of 2012, to the lowest level in a decade, leading to a switch to gas-fired power generation and less coal-fired power generation. Compared to coal, natural gas contains roughly about half the amount of carbon (C) per unit of energy; therefore, gas-fired electricity generation produces about half as much CO2 as that from coal. In addition, since they operate at a higher temperature, gas- fired plants can achieve up to almost 15 percentage points higher energy efficiency than coal-fired power plants. Thus, this shift from coal to less carbon-intensive natural gas resulted in a decrease in CO2 emissions. In addition, a 2.2% decrease in transport emissions (but no change in biofuel consumption) and mild winter temperatures reducing the demand for space heating also contributed to the decrease. In the United States, the demand for air conditioning in the summer months may also significantly influence annual trends in fuel consumption.

Although higher natural gas prices, later in the year, reduced the gas share in power generation below the record level of April 2012, the share of coal in power generation on average remained about 10 percentage points below the annual range of 48% to 51%, prior to 2009 MacMillan et al. (2013) and EIA provide further insight into the fuel price incentives for coal- or gas-fired power plant operators and into the reasons for the natural gas price developments in 2012 and early 2013.CO2 emissions from fossil-fuel combustion decreased by 13% in 2012, thus falling below 2005 levels. Houser and Mohan analysed the causes of the decrease for the United States, and concluded that the shift from coal to natural gas in power generation, from 20% in 2008 to 30% in 2012, contributed greatly to this change, but the increase in the share of renewable energy in power generation, from 7.9% in 2005 to about 11% in 2012, contributed as much. Houser and Mohan conclude that the total reduction in the carbon intensity of the US energy mix from 2005 to 2012 for about 40% was due to the shift towards natural gas, for 25% due to the shift towards wind energy, for 25% due to more use of biofuels and for the remaining 10% due to solar energy, hydropower and nuclear power. These changes contributed to about half the decrease in CO2 emissions, the other half was due to a much slower economic growth; between 2005 and 2012, GDP grew on average by 1.1%, annually, compared to 3.1% between 1990 and 2005. However, Shellen Berger et al.(2013) claim that this analysis ignored the 10% decline in the energy intensity of the economy in 2012, compared with 2005, due to more efficient gas-fired power generation than the previous coal-fired plants, increases in energy efficiency in other sectors, and economy-wide sect oral shifts Moreover, they point out that renewable energy not only replaced coal-fired power, but rather several specific mixes of fuels, differing per region. In their response, Houser and Mohan addressed these issues and concluded that regardless of how large the role of natural gas has been in CO2 reductions to date, recent data and forecasts suggest that 'it will take new policy to extend those emission cuts forward as both the economy and the natural gas prices begin to recover'.

Natural gas prices in the United States are determined by the North American gas market. By 2012, the production of natural gas increased by 28.9%, relative to 2006. Shale gas production started in 2007 and, by 2013, it had already a one-third share in total US gas production. In comparison, production of shale oil started around 2005 and by 2012 had a share of almost one-quarter in total US crude oil production .

3) European Union

The European Union, as a whole, remained in an economic recession in 2012; its GDP in that year declined by 0.3% compared to 2011. However, CO2 emissions declined by 1.3% in 2012 compared with 2011 (1.6% with leap-year correction), less than the 3.1% decrease in 2011. The main causes of the decline are:

– Decreasing emissions in the EU's primary energy consumption of oil and gas by 4% and 2%, respectively. These decreases were mainly driven by a 1% reduction in electricity production and a reduction in emissions from the residential and services sectors, despite the colder winter.
– Decreasing transport emissions in the EU, determined from a decrease in road freight of 4.1% and air freight of 18.4% between 2011 and 2012. Only rain and sea freight increased by 0.9% and 1.3%, respectively.
– A 2% decrease in emissions from the power plants and manufacturing industry installations in the EU27 participating in the EU Emissions Trading System. This includes a 4.5% emission reduction in the iron and steel industry between 2011 and 2012. All EU countries (except the United Kingdom and Slovakia) saw a decline in 2012; in particular, Bulgaria and Spain, with 24.2% and 12.6%, respectively. The chemical industry remained fairly constant, with only a slight increase of 0.8% in Germany. Finally, a slight decrease in emissions from cement production; in particular, with a decrease between 2011 and 2012 in Spain with 10% and Italy with 3%. Only in Germany cement production increased by 1.5%.

The United Kingdom has not constructed any new coal fired power plants over the last decade. Moreover, it is phasing out these plants, having already converted 3 plants to biomass with a total capacity of 5,160 MW, and has closed another 4 coal-fired plants with a total capacity of 14,670 MW. Spain has also decreased the share of coal in its power generation, considerably, and continues to do so by quadrupling the tax rate on coal and not renewing the subsidies for such coal-fired plants. Since 2010, Spain has been delivering more than 20% of its electricity from renewable sources by widespread deployment of wind power and is investing further in wind and solar technologies.

4) India

India, where domestic demand makes up three quarters of the national economy, has been relatively unaffected by the global financial recession because this recession in fact stimulated the already high share of domestic consumption in total national expenditure. Nevertheless, India's GDP growth of about 4% in 2012 was the lowest in a decade. India's CO_2 emissions in 2012 continued to increase by 6.8% to about 2.0 billion tonnes , making it the fourth largest CO_2 emitting country, following the European Union, and well ahead of the Russian Federation, which is the fifth largest emitting country. This high ranking is partly caused by the size of its population and economy. Per capita, India's CO_2 emissions were much lower than those of most developed countries and China. The increase in 2012 mainly was caused by a 10% increase in coal consumption, which accounted for two thirds of India's total emissions from fossil-fuel combustion and 55% of those from its electricity production. This growth rate was much higher than in the previous two years, but similar to those of 2008 and 2009. Coal-based power production, accounting for almost 70% of all of India's coal-related CO_2 emissions, grew by about 13% in 2012, the highest annual growth ever. Both the additional capacity and generation level were higher. Although not as large as those of China and South Africa, which had a 75% share of coal in their fossil-fuel mix, India's share was also large with 57%. Poland and Kazakhstan, other countries with large coal resources, had similar coal shares, whereas the global average share in 2012 was about 34%.

5) Russian Federation

In 2012, the Russian Federation alone accounted for a share of 5.1% in global CO_2 and this represented half of the emissions from the so-called economies in transition. After the large decrease of 5.6% in emissions in 2009, due to the global recession, the Russian Federation in 2011 recorded an increase of 4.1% in emissions over the last twenty years, going back to the CO_2 emissions level of 2006. However, in 2012, CO_2 emissions in the Russian Federation decreased by 0.9%. The eastern European countries, excluding the Russian Federation and EU's 12 new Member States, recorded an increase of only 1% in 2012, increases in CO_2 emissions in 2010 and 2011 of about 8% and 6.6%, respectively.

6) Japan

The share of Japan in global CO_2 emissions decreased slowly, from 5.2% in the 1990s, to 4.5% in following decade, to 3.8% in 2012. However, economic recovery following the recession of 2009 and the closure of nuclear plants after the Fukushima accident led to the highest increases in CO_2 emissions of the past twenty years, with 6.2% in 2012. The increase in 2012 was partly due to a 5.4% increase in the use of coal, with consumption levels back at those of the years 2007 to 2010. Following the nuclear disaster in 2011, renewable energy in Japan is seen as an alternative for the future and could account for about one-fifth of Japan's energy mix by the 2020s. Renewable energy in 2012 accounted for about 10% of the energy supply, most of which from hydroelectric sources. At the end of 2012, Japan's total solar capacity reached 7.4 GW and this is expected to grow further.

7) Other Developing Countries

In 2012, emissions from the category of 'other developing countries' represented more than one fifth of the total in global CO_2 emissions, with South Korea having a share of 1.8%, and Indonesia and Mexico 1.4% each. After the economic recovery in most of these countries following the recession of 2009, large increases in CO_2 emissions were recorded for 2010. However, in the subsequent years, CO_2 emissions increased much less. Total CO_2 emissions in these 'other developing countries' increased by 2.9% in 2011 and 2.5% in 2012, down from the large jump of 5.5% in 2010, following the economic recovery in these countries after the global recession of 2009. Of the larger of these countries, CO_2 emission levels in South Korea and Indonesia did not change in 2012, compared to 2011, but increases were seen in Saudi Arabia (7%), Mexico (4%) and Brazil and Iran (both 2%).

B. Comparison of Carbon Emissions in Various Countries

Although emissions in China and other countries with emerging economies increased very rapidly in recent years, in both relative and absolute figures, the picture is different for CO_2 emissions per capita and per unit of GDP Where, since 1990, in the EU27, CO_2 emissions decreased from 9.1 to 7.4 tonnes per capita, and in the United States from 19.6 to 16.4 tonnes per capita, they increased in China from 2.1 to 7.1. As such, Chinese citizens, together representing 20% of the world population, on average emitted about the same amount of CO_2 per capita in 2012 as the average European citizen.

The EU27 saw a decrease of 1.3% in total CO_2 emissions from fossil fuel and cement production between 2011 and 2012, which is a smaller decrease than in the United States (3.7%). China's total CO_2 emissions increased by 3.3%, and for India this was even more, with 7.1%. Japan, with 6.5%, showed one of the strongest increases in total CO_2 emissions, mainly due to the use of fossil fuel instead of nuclear energy in their power generation.

Over the past decade, all countries experienced a declining trend for CO_2 in terms of GDP, but the ranking order of countries more or less remains the same: with a lower emission level in the European Union; Japan emitting less CO_2 per invested USD in GDP than all the other countries of the world; medium levels in the United States and India; and higher levels in the Russian Federation and China, the last two emitting relatively high amounts of CO_2 per USD of GDP. The trends for the Russian Federation and China were less smooth; partially due to very large and fast changes in their economies. In 2012, the emission intensity of the EU was about three quarters that of the United States and about one third that of China. The higher levels for the Russian Federation and China indicated a larger share of more energy- intensive economic activities, the use of less energy-efficient technologies, a larger share of coal in the energy mix, or a combination of these factors.

III. EFFECTS OF CARBON EMISSION ON SNOW MELTING

Snow and ice on land, in the sea, and in the ground are part of what is known as the cryosphere. Snow and ice are important components of the Earth´s climate system and are particularly vulnerable to global warming. Reduction of snow and ice contributes to an acceleration of global warming through feedback processes. Loss of snow and ice will impact the cultures and livelihoods of people around the world.

A. Changes in Snow and Ice Affect the Global Distribution of Heat

- Snow and ice reflect most solar radiation back to space, while open sea and bare ground absorb most of the solar radiation as heat. When snow and ice disappear, the areas normally covered will warm, contributing to further melting and warming through a self-reinforcing effect.
- Large amounts of methane and carbon dioxide (CO2) are stored in the world's permafrost regions.
- Melting of sea and land ice influence ocean temperature and salinity, which are important factors in the development and movements of the major ocean currents. Any changes to these may significantly alter the ocean current system and the global transport of heat.

B. Changes Caused by Melting Snow and Ice Affect People's Homes and Livelihoods Worldwide

- Sea level rise is one of the most obvious consequences of melting ice on land. Even quite minor melting of ice masses will have major consequences for people and infrastructure in coastal communities, cities, and states.
- Melting of high mountain glaciers can have consequences for the availability of water for agriculture, domestic use, hydroelectric power stations, and industry. Melting of high mountain glaciers can also lead to hazardous conditions, particularly in the form of glacier lake outburst floods, which can significantly impact human populations and activities.
- The ecosystems and biodiversity in polar and mountain regions can change significantly as snow and ice cover diminishes. People depending on the natural resources of these regions will need to adapt to these changes.
- Access to resources may become easier as snow and ice disappear, but may also lead to challenges with respect to safety and pollution issues.

C. Snow and Ice Feedback Processes

Processes which contribute to the amplification or decrease in the rate of a change are called feedback mechanisms. Fig.3.1 shows examples of climate feedback processes caused by changes related to the cryosphere.

Snow-covered ice typically reflects around 80% of the sunlight it receives, whereas open water absorbs more than 90%. When snow and ice begin to melt darker land and water surfaces are revealed, and these darker surfaces absorb more of the sun's heat, causing more warming, which causes more melting, and so on. As the ocean warms, subsea permafrost thaws, releasing methane into the atmosphere. Methane is about 25 times more potent as a greenhouse gas than CO2. Declining snow cover accelerates local atmospheric heating by reducing the reflectivity of the surface, contributing to the further decrease of snow cover. As temperatures rise, near-surface permafrost thaws, increasing the flux of carbon into the atmosphere, feeding back to further climate change. Higher temperatures could, however, also lead to increased vegetation growth and thereby higher carbon uptake, offsetting some of the amplifying effects described above.

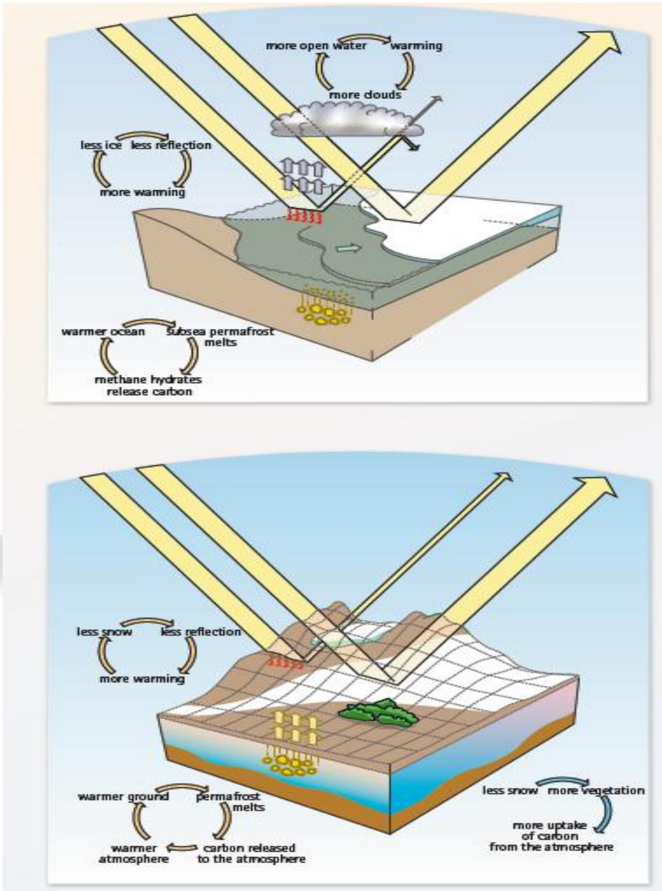

Fig. 3.1: Snow and Ice Feedback Mechanism

IV. MELTING OF GLACIERS AND ICE CAPS

Glaciers around the globe have been shrinking since the end of the Little Ice Age, with increasing rates of ice loss since the early 1980s. The ongoing trend of worldwide and rapid glacier shrinkage may lead to the complete de-glaciations of large parts of many mountain regions by the end of the 21st century. The glaciers of the region are found in the headwaters of several of Asia's great river systems, including the Indus, Ganges/Brahmaputra, Mekong, Yangtze, and Yellow Rivers. These rivers are the source of drinking water and irrigation supplies for roughly 1.5 billion people. They also generate significant quantities of hydroelectric power and support important ecological and cultural amenities and services. The surface water of these rivers and associated groundwater constitute a significant strategic resource for all of Asia, which is among the most water stressed regions of the world (Smakhtin, 2008). The Himalayas are the youngest and highest mountains of the world and have the largest concentration of glaciers outside the polar caps, with glacier coverage of 33,000 square kilometers. The region is aptly called the "Water Tower of Asia" as it provides around 8.6×106 m3 of water annually. Glaciers in the Himalayas feed many important rivers of Asia including Ganga, Amu Darya, Indus, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, Yellow, and Tarim. Apart from feeding the rivers, the Himalayas also play a significant role on the meteorological condition of India. As it is well established that the climate is changing, the same is reflected from the glacier behaviors in terms of size, health and runoff.

Figure 4.1 shows the percentage of glaciated area within the river basins of the HKH region. The Indus, Ganges, and Brahmaputra basins combined contain nearly three-quarters of the region's glaciated area. With the exception of the Interior basins the other river basins each contain less than five percent of the region's glaciated area.

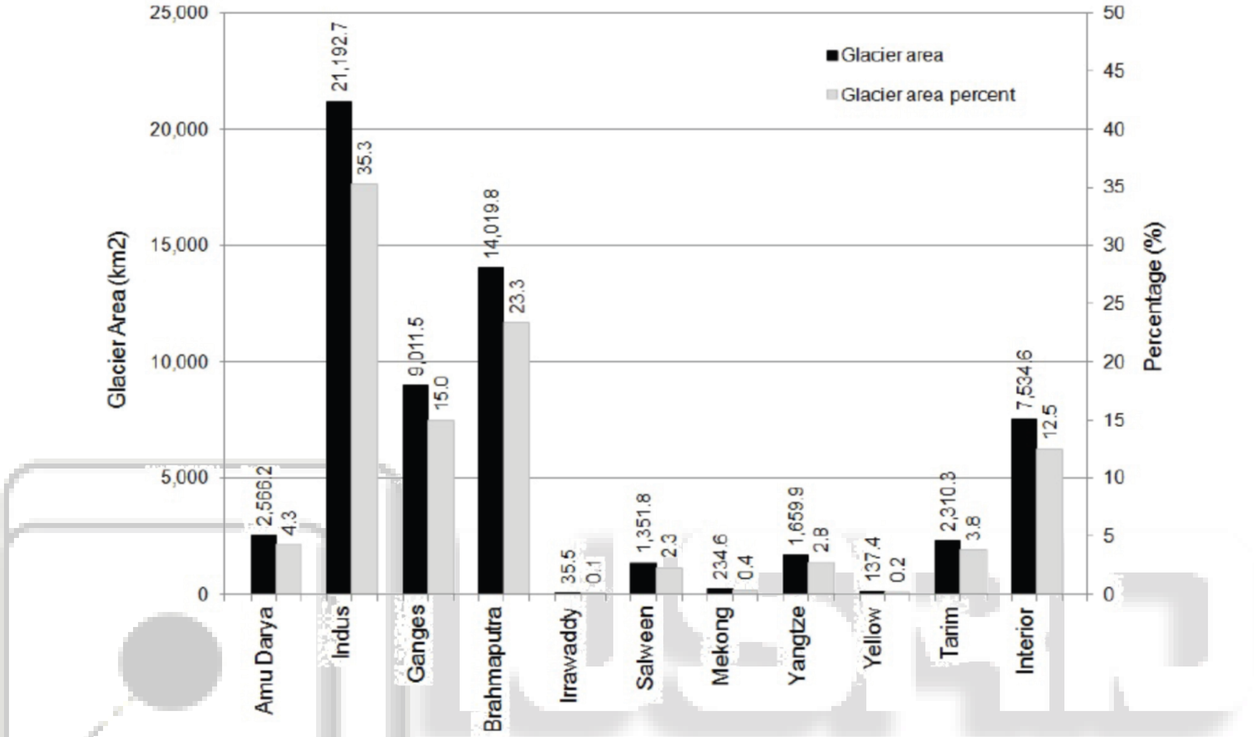

Fig. 4.1: Glacier area and percentage of total HKH glaciated area in each of the region's river basins.

With the 27 km long Gangotri glacier shrinking, there is now less water downstream to dissolve the chemical wastes of over a 100 industries that pour into the river. With less water, the density of pollutants in the Ganga keeps increasing. These glaciers are a primary source of water for 30 to 50 per cent of the major rivers in the Gangetic plain. Recession may cause an increase in the discharge of Himalayan rivers due to enhanced melting, initially leading to a higher incidence of flooding and landslides.

Many studies have been carried out on the fluctuation of glaciers in the Indian Himalaya and significant changes (mostly retreats) have been recorded in the last three decades. The retreat of selected glaciers is summarized in Table 1. Most of these glaciers have been retreating discontinuously since the post-glacial period. Jeff Kargel of the USGS showed that the position of the Gangotri Glacier snout retreated about 2 km in the period from 1780 AD to 2001 and is continuing to retreat. Almost all the glaciers of Himalaya and Karakoram are receding with varying rate. Gangotri glacier, source of river Ganga is receding at alarming rate, which has adverse impact in Himalayan Ganga basin.

Glacier	Period	Retreat of Snout (meter)	Average Retreat of glacier (m/yr)	Glacier length (km)	Years to disappear
Triloknath Glacier (Himachal Pradesh)	1969 to 1995	400	15.4`	5	324.7
Pindari Glacier (Uttaranchal)	1845 to 1966	2,840	135.2	3	22.2
Milam Glacier (Uttaranchal)	1909 to 1984	990	13.2	16	1212.1
Chhota Shigri Glacier (Himachal Pradesh)	1986 to 1995	60	6.7	9	1343.3
Bara Shigri Glacier (Himachal Pradesh)	1977 to 1995	650	36.1	11	304.8
Gangotri Glacier (Uttaranchal)	1977 to 1990	364	28.0	30	1071.4

Gangotri Glacier (Uttaranchal)	1985 to 2001	368	23.0	30	1304.3
Zemu Glacier (Sikkim)	1977 to 1984	194	27.7	26	938.6

Table.1 Record of retreat of some glaciers in the Himalaya

The annual meeting of glacial ice provides important water resources for downstream populations and ecosystems, particularly in arid areas of the Himalayas and during the critical seasonal dry periods. The supply of water resources, or the snow-and-ice-melt water component, is projected to increase in the coming decades as the perennial covering of snow and ice decreases. On a longer-term scale, however, water scarcity, particularly during the dry season, is likely to be a future challenge (Eriksson et al. 2008)

Glacier in the Dudh-Koshi basin of the Everest region retreated almost 1600 m between 1962 and 2001 and another 370 m by 2006. The Gangotri Glacier in Uttaranchal, India, retreated about two km between1780 and 2001 (WWF 2005). Gangotri glacier, which had hitherto been showing a rather rapid retreat, along its glacier front, at an average of around 20 m per year till up to 2000 AD, has since slowed down considerably, and between September 2007 and June 2009 is practically at a standstill. Chhota Shigri glacier is located in climatically important region of the Himalayas. The glacier lies in the Chandra basin that is a sub basin of Chenab Basin and comes under Himachal Pradesh, India. The glacier is located in the monsoon-arid transition zone. The glacier is considered to be a potential indicator of the northern limits of the intensity of the monsoon. The glacier is influenced both by the Indian summer monsoon and by western disturbances in winter. The glacier is 9 km long and is located between 32°11′ – 32°17′ N and 77°30′ -77°32′ E and occupies an elevation of 4000 to 5660 m.

Fig. 4.2(a): Retreat of Chhota Shigri Glacier in 1973

Fig. 4.2(b): Chhota Shigri Glacier in 2006

Chhota Shigri was selected as the benchmark glacier in the HKH region by the International Commission of Snow and Ice (now this is Commission of Cryospheric Science) in 2002. Continuous field mass balance measurement was carried out on the glacier by a joint team of Indian and French researchers from 2002-2007. The glacier has shown negative mass balance for last 20 years. The cumulative specific mass balance of Chhota Shigri glacier from 1986-1989 was 0.21.m.w.e. A study on the ELA (ELA (Equilibrium line altitude) is a theoretical snow line at which the glacier mass balance is zero) variation of the glacier has shown that the ELA has an average rate of upward shifting by 31 meters per year from 1987- 2006.

A. Measurements Indicate That the World's Glaciers and Ice Caps Are Losing Mass and Retreating

- Mass balance measurements are the primary quantitative measure for assessing the response of glaciers to the climate. It should be noted that mass balance measurements prior to 1976 are only available for the Northern Hemisphere and are strongly biased towards Europe. Over the last decades the greatest mass losses per unit area have been observed in the European Alps, Patagonia, Alaska, northwestern USA, and southwestern Canada. Alaska and the Arctic are the most important regions with respect to total mass loss from glaciers, and thereby to sea level rise.
- Length change measurements show a general global glacier recession from their maximum positions during the Little Ice Age. Within this general retreat trend there have been intermittent periods of re-advancing glaciers, for example, in coastal Scandinavia and New Zealand's Southern Alps in the 1990s, which mainly were due to increased winter precipitation. The glaciers in these areas have recently been reduced, both in volume and length. Information from glacier length change studies supplements the findings of mass balance studies, supporting the findings of a global and centennial negative trend002E
- The Himalayas is among the regions with the least available data. Although glacier retreat is widespread here, records of glacier fluctuations are extremely sparse and do not allow a sound quantitative comparison of change rates with other regions.
- Iceberg calving is a significant source of mass loss from many large ice caps, accounting for 20–40% of the total mass loss in several cases. Changes in the dynamics of calving tidewater glaciers and ice cap outlets can be abrupt and can produce large changes in the rate of mass loss by calving.
- Floating ice shelves also calve. In some areas, the extent of ice shelves is decreasing substantially. Major disintegration events have also taken place on the ice shelves around the Antarctic Peninsula.

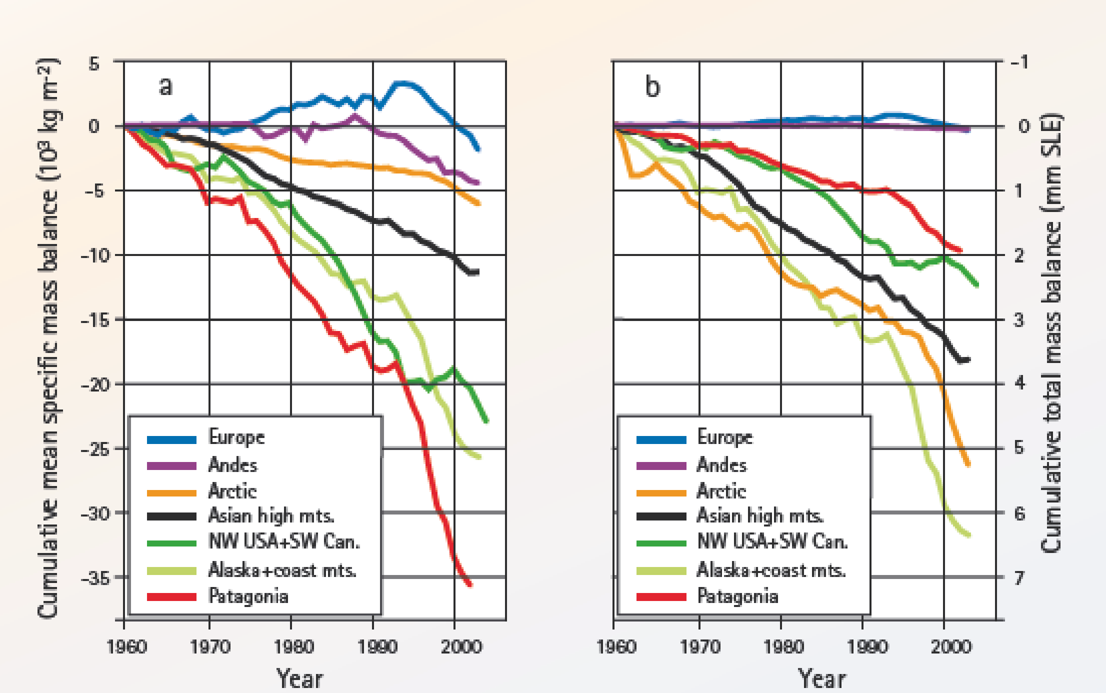

Fig. 4.3(a): Cumulative Glacier mass balance for selected glacial systems (b) Cumulative contribution to sea level.

B. *Glacier Mass Loss*

Mass balance measurements are the primary quantitative measure for the climate-glacier relation. The figure 4.3 shows cumulative mass balance change based on available data from six decades of annual mass balance data. Over the last decades the strongest mass losses per unit area have been observed in the European Alps, Patagonia, Alaska, northwestern USA, and southwestern Canada (a). However, cumulative total mass loss has been largest in Alaska and the Arctic, and these areas are therefore most important as contributors to sea level rise (b). It should be noted that the data in some regions, such as the Himalayas, are based on short time series from few glaciers.

V. CONTROL MEASURES AND REMEDIAL STRATEGIES

There are three primary methods for reducing the amount of carbon dioxide in the atmosphere: employing energy efficiency and conservation practices; using carbon-free or reduced-carbon energy resources; and capturing and storing carbon either from fossil fuels or from the atmosphere.

A. *Efficiency and Conservation*

There are many energy efficiency and conservation practices that reduce the consumption of carbon-based fuels (e.g., natural gas, oil, coal, or gasoline), decreasing carbon dioxide emissions. Such as:

- Preventing and limiting the cause of climate change, by cutting back on production of greenhouse gases and planting more forests.
- Afforestation programme can help in controlling the phenomena of global warming and thus its devastating impacts in several ways. In Gangotri-Gaumukh region, afforestation programmes are going on by governmental organizations, NGOs and local people.
- Hydrological models should incorporate better physical based understanding of processes and their interaction. Parameter measurement and estimation techniques must be developed further for using over a range of spatial and temporal scales.
- Maintenance and installation of observation network for the Himalayan region to monitor and evaluate the impacts of climate change. International research organization and funding agencies should focus on areas with scarce data.
- Budget planning should permit sufficient flexibility to accommodate departments to deal with extreme climatic events.
- Better communication and interaction between planners, researchers, and policy makers are needed. Better cooperation and support among neighboring countries are needed to cope with climate-induced disasters.
- Involvement of community is important at all decision-making levels. It helps in generating more awareness of climate change issues and develops a better understanding of the impacts and potential adaptation measures available to decision-makers and local level community.
- Monitoring and evaluation programs should be implemented as an ongoing activity to determine if supplemental adaptation measures need to be considered.

B. *Carbon-Free and Reduced-Carbon Energy Sources*

Carbon-free sources of energy have their own associated impacts, but in general, these technologies generate energy without producing and emitting carbon dioxide to the atmosphere. Carbon-free energy sources include solar power, wind power, geothermal energy, low-head hydropower, hydrokinetics (e.g., wave and tidal power), and nuclear power. Alternatively, switching from high-carbon fuels like coal and oil, to reduced-carbon fuels such as natural gas, will also result in reduced carbon dioxide emissions. The extent to which biomass energy is considered to be carbon-free or a reduced-carbon fuel depends on the type of biomass used and the processes by which it is converted to energy.

C. Carbon Capture and Sequestration

Carbon sequestration involves the capture and storage of carbon dioxide that would otherwise be present in the atmosphere, contributing to the greenhouse effect. As described on the Carbon Sequestration Approaches and Technologies page, carbon dioxide can be removed from the atmosphere and retained (stored) within plants and soil supporting the plants. Alternatively, carbon dioxide can be captured (either before or after fossil fuel is burned) and then be stored (sequestered) within the earth.

VI. CONCLUSION

Global emissions of carbon dioxide (CO2) the main cause of human-induced global warming increased by only 1.1% in 2012, yielding a slowdown in annual global CO2 emissions, at 34.5 billion tonnes in 2012. While the past decade saw an average annual CO2 emission increase of 2.7%, in 2012 the actual increase was only 1.4% (1.1% after leap-year correction). Nevertheless, in 2012, the mean annual global growth rate of atmospheric CO2 concentrations was rather high with 2.4ppm. Inter- annual variation in net carbon storage of forests and absorption by the oceans could explain this difference in trends. In May 2013, an unprecedented concentration CO2 level of more than 400ppm was measured in the atmosphere, up from 355ppm in 1990. Scientific literature suggests that limiting average global temperature rise to 2 °C above pre-industrial levels - the target internationally adopted in UN climate negotiations is possible if cumulative CO2 emissions over the 2000-2050 period do not exceed 1,000 to 1,500 billion tonnes (Meinshausen et al., 2009). Since 2000, an estimated total of about 466 billion tonnes CO2 was cumulatively emitted due to human activities (including deforestation), according to the EDGAR statistics with an uncertainty range of ±10%.

Obviously, it is uncertain how the global society will develop, over time, and which economic and technological trends will continue, in particular the global and regional prices of different fossil fuels and the shares of nuclear power and renewable energy sources. However, there also is additional uncertainty due to possible major changes in various areas that have a large impact on global energy use ; for example, an increase in the production of shale gas may affect natural gas prices worldwide; expansion of intercontinental trade in LNG through increased transport and storage capacity may influence natural gas markets; overcapacity and flexibility in fuel mix for power generation may cause rapid changes in the fuel mix of utilities in case of changes in the relative price of gas and coal (as observed in the United States and some European countries); the ability of China to make a smooth transition towards a more service-based economy ; and a prolonged recession may hinder the functioning of the carbon market of the EU ETS being restored and, thus, the ability to set and meet more ambitious emission reduction targets.

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